Avoiding Sustainability Tradeoffs (in the Energy Transition)

Elisabeth H. Krueger, PhD

Future of Energy Seminar, October 16, 2023

University of Amsterdam

Who I am…

Current

Assistant Professor

– teaching & research

Institute for Biodiversity and Ecosystem Dynamics — FNWI

Amsterdam Institute for Social Science Research (AISSR) — FMG

Background

- **MSc** University of Freiburg ***Environmental Hydrology***
- **Research Manager** at Helmholtz Centre for Environmental Research: Coordination of ***interdisciplinary water research projects***
- **PhD** Purdue University: ***Urban water resilience & sustainability in arid areas*** (Jordan)
- **Postdoc** Princeton University: ***Governance & human behaviour for sustainability***

Why I am here…

1. **ENLENS grant** (with John Grin): How much biomass for the Dutch economy?

→ Master theses research

2. **Energy transition in North Holland** (Yael Artzy-Randrup with John Grin, Colin Hickey)

→ Fabian Dablander (Postdoc)

How sustainable are renewables?
(ENLENS Master theses, with John Grin)

1. How much biomass for the Dutch economy?

MSc thesis Gabriele La Bruna:

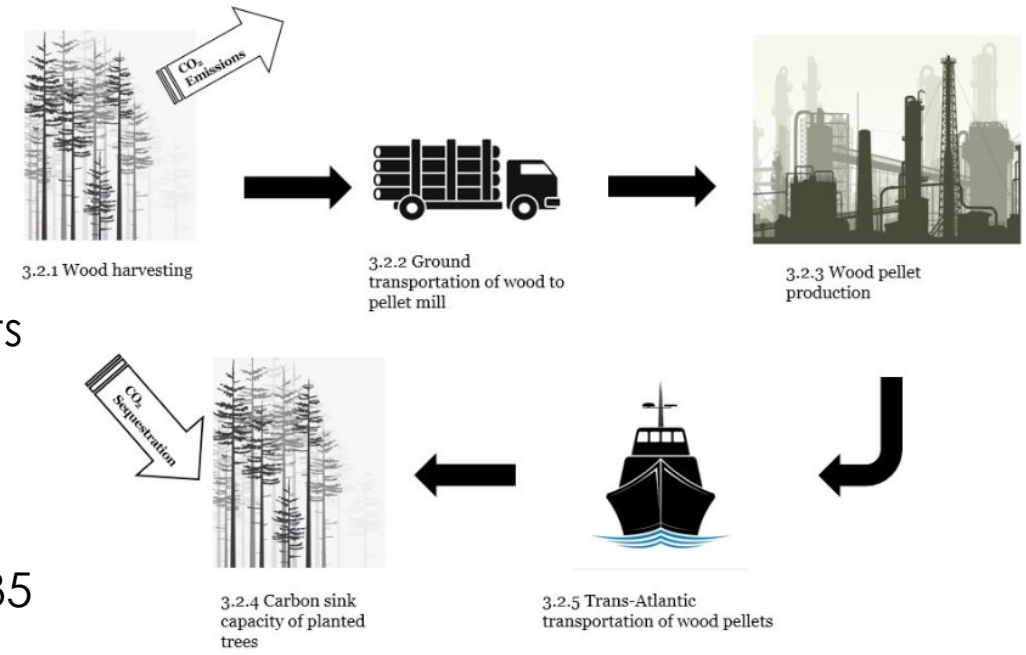
→ Accounting methods for carbon-neutrality of biomass do not account for CO_2-sequestration of replanted forests (assumes neutrality).

Example: Enviva wood pellet supply chain analysis

→2.7 Mt of wood pellets imported to NL in 2020 (8.7 Mt CO_2e) would require replanting 16,000 ha of forest for 35 years.

→Plans of the company 2019: 14.000 ha in 10 years for a total of 6.2 Mt/yr

(2020 plans according to GreenTrees: 10.000 ha per year for production of 13 Mt/yr)



How sustainable are renewables?
(ENLENS Master theses, with John Grin)

2. Wind energy siting

MSc thesis Mitchell Keipp

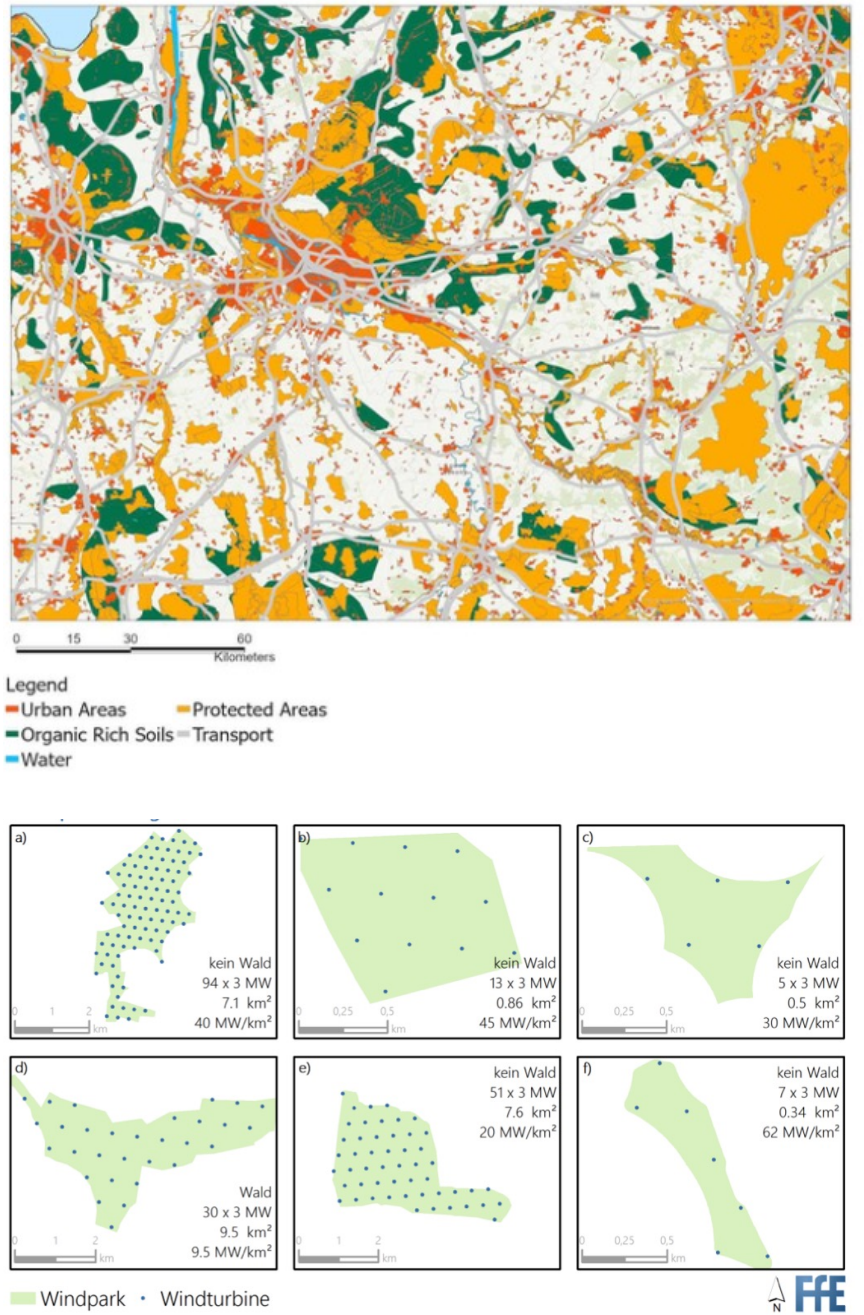
→ risk of releasing soil carbon through installation of wind turbines, in particular in peat lands

Example: Onshore wind goals for Germany
(from current 58GW to 160GW by 2035)

→Degraded peat in Germany (used for agriculture) is responsible for 5.7% of GHG emissions.

→ Wind turbines installed on peat emit avg. 560 gCO_2e/kWh (compare gas-powered electricity: 450 gCO_2e/kWh). Peat-rich soils: 1 750 gCO_2e/kWh (comparable to coal).

→ Peat-rich soils are not excluded from siting decisions!



How sustainable are renewables?
(ENLENS Master theses, with John Grin)

3. Burden-shifting and social injustices

MSc thesis Sol Agüero

→ How is social justice considered?

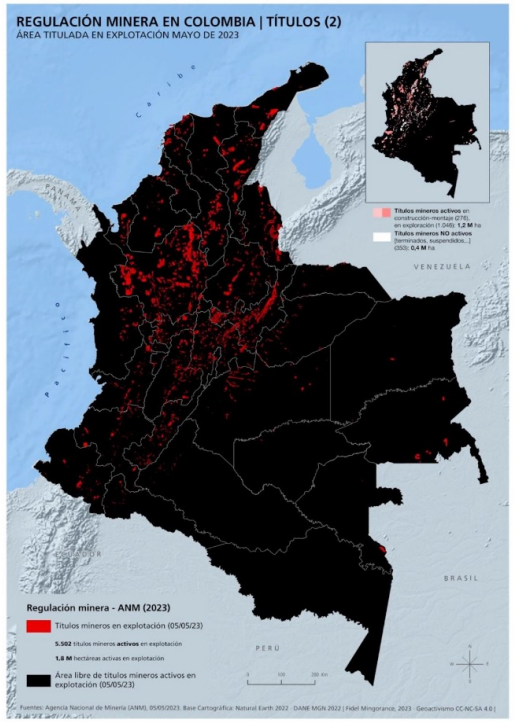
Example: Colombia's energy transition strategy.

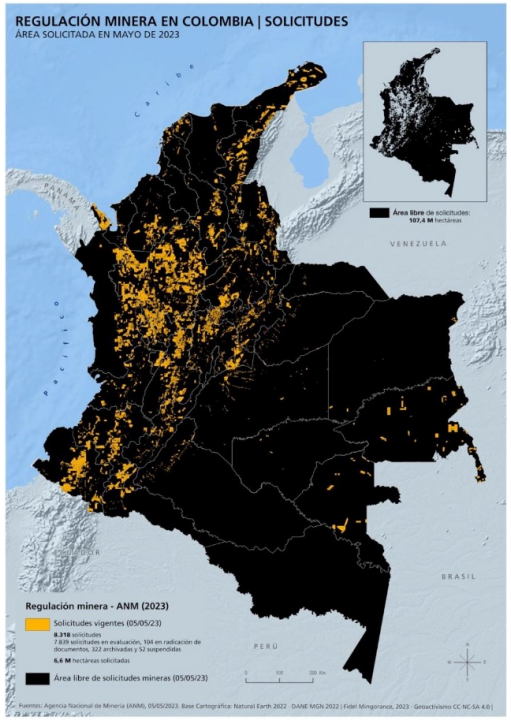
→Mining sector: 50% of exports, 20% of GDP (coal, oil, gas, nickel, gold, platinum, silver, copper)

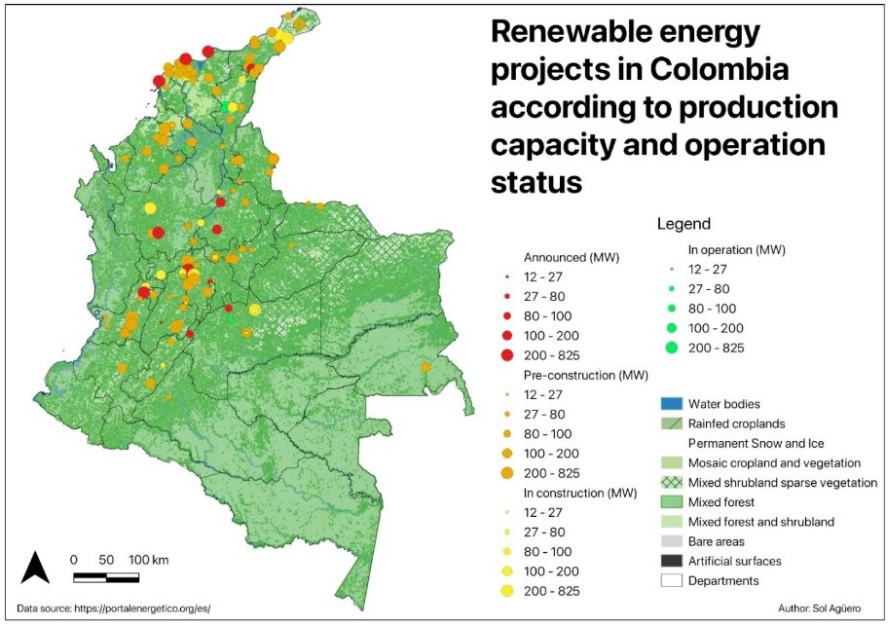
→ Mining & RE projects affect marginalized populations & biodiversity hotspots!

→ Transition or addition of renewable energy sources & mining projects to existing energy system?

- → 70% hydroelectricity
- → 30% of emissions related to energy (60% AFOLU)







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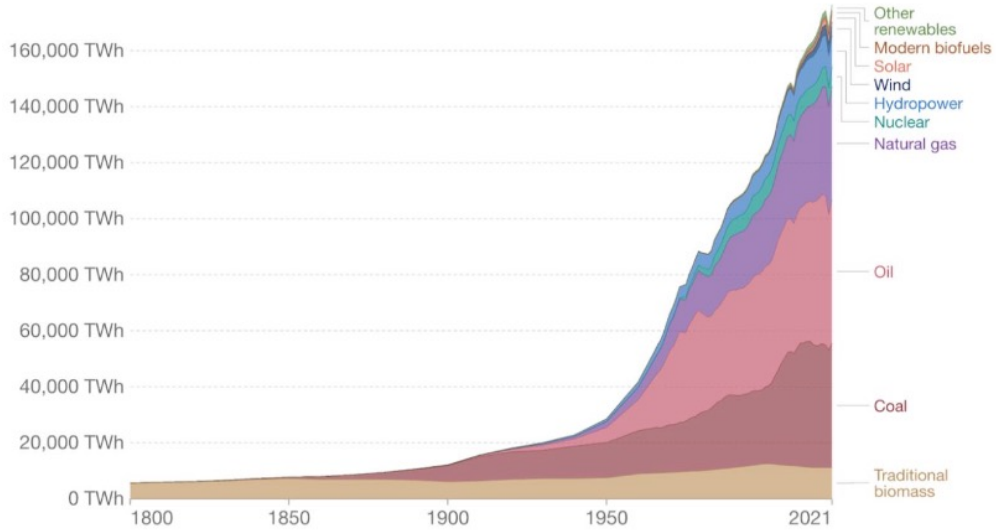
Global Primary Energy by Source

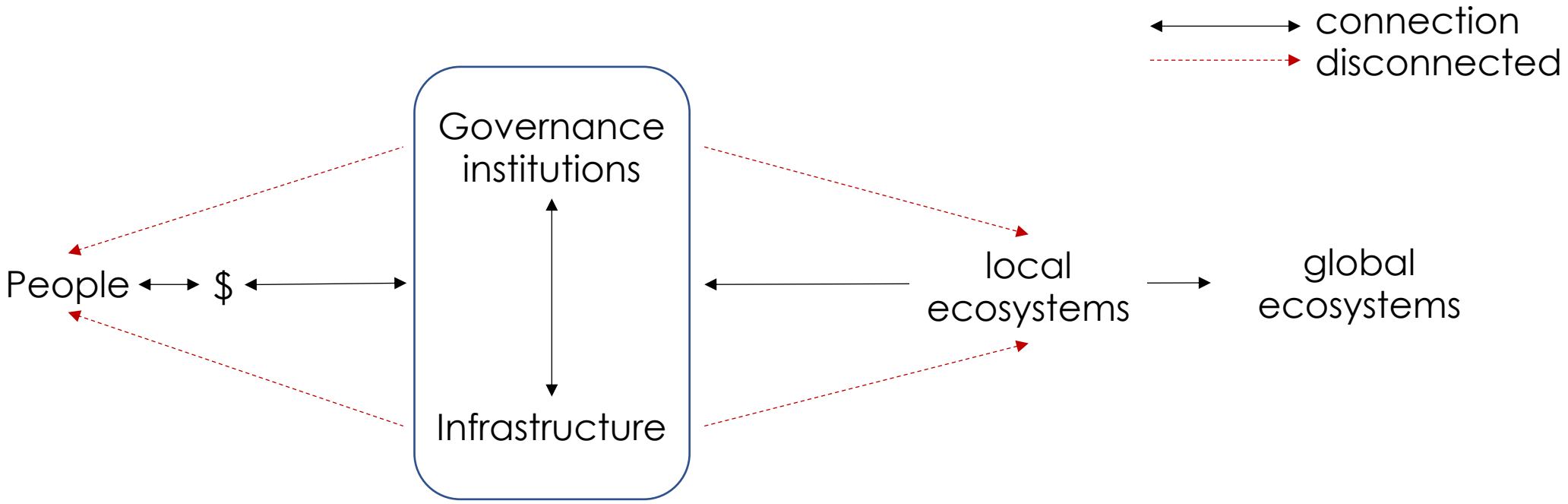


Note. "Primary energy is calculated based on the 'substitution method' which takes account of the inefficiencies in fossil fuel production by converting non-fossil energy into the energy inputs required if they had the same conversion losses as fossil fuels" (Ritchie, 2021). Figure created by Ritchie, 2021.

Acceleration of energy transition under false assumptions may only shift, not solve, the problem!

Transition to what and how?

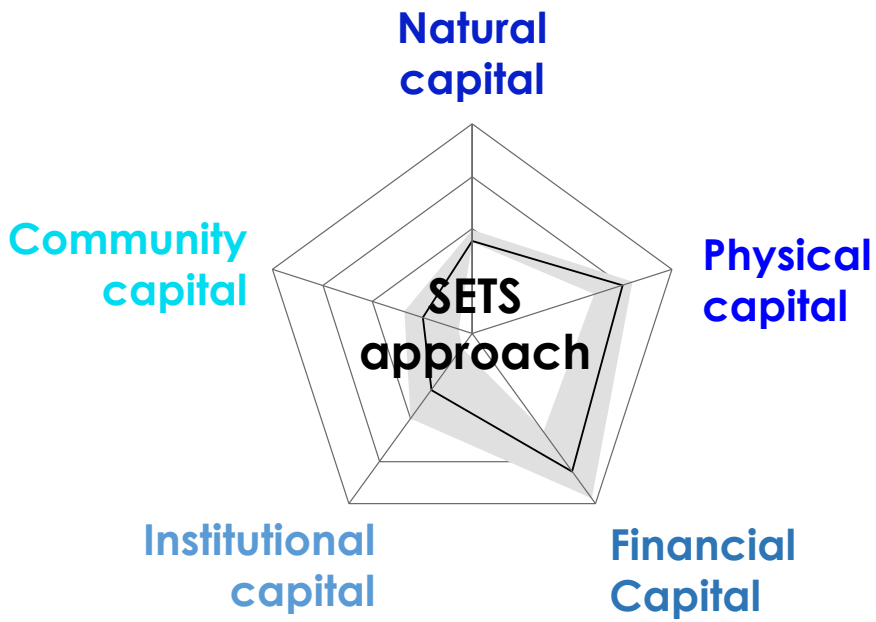
Human-environment interactions mediated by infrastructure & institutions



- **Do infrastructures (technologies) and institutions promote or degrade sustainability efforts?**

Research Approach 1: Social-Ecological-Technological System (SETS) providing services to the public (water, energy, food)

Citizen perspective: **Services**



E.g.,

- water
- land
- natural resources
- ecosystem services

- built infrastructure
- technologies

- investments
- salaries/wages
- subsidies

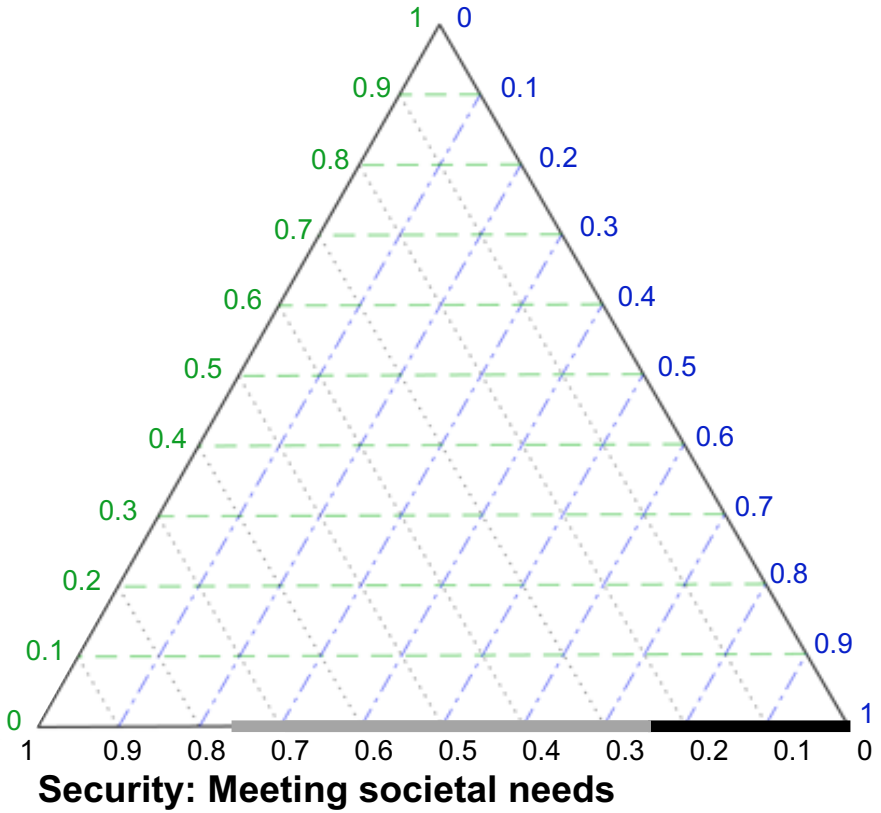
- rules, regulations, policies
- effective management

- adaptive capacity
- community support/ opposition
- individual & group behaviour

Krueger et al. (2019) GEC

Research Approach 2: Balancing Security, Resilience & Sustainability

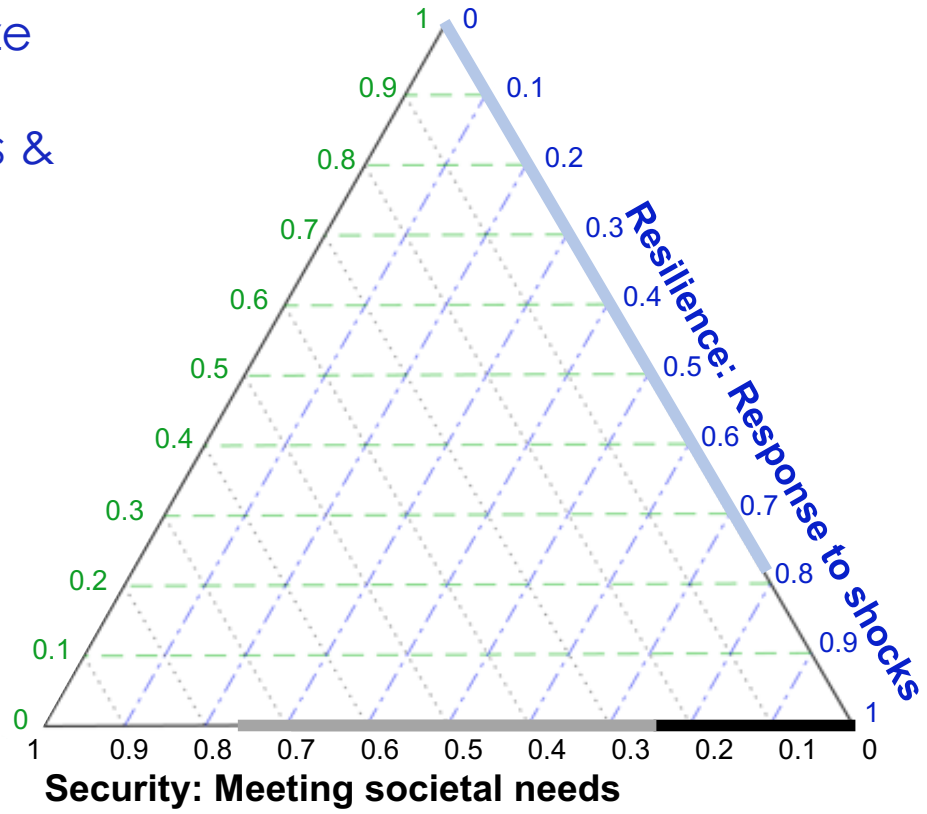
Security: Current state of service provision for all



Krueger et al. (2020) ERL

Research Approach 2: Balancing Security, Resilience & Sustainability

Resilience: Response to shocks – buffer, recover from, reorganize system elements to maintain functions in response to shocks & uncertainty



Krueger et al. (2020) ERL

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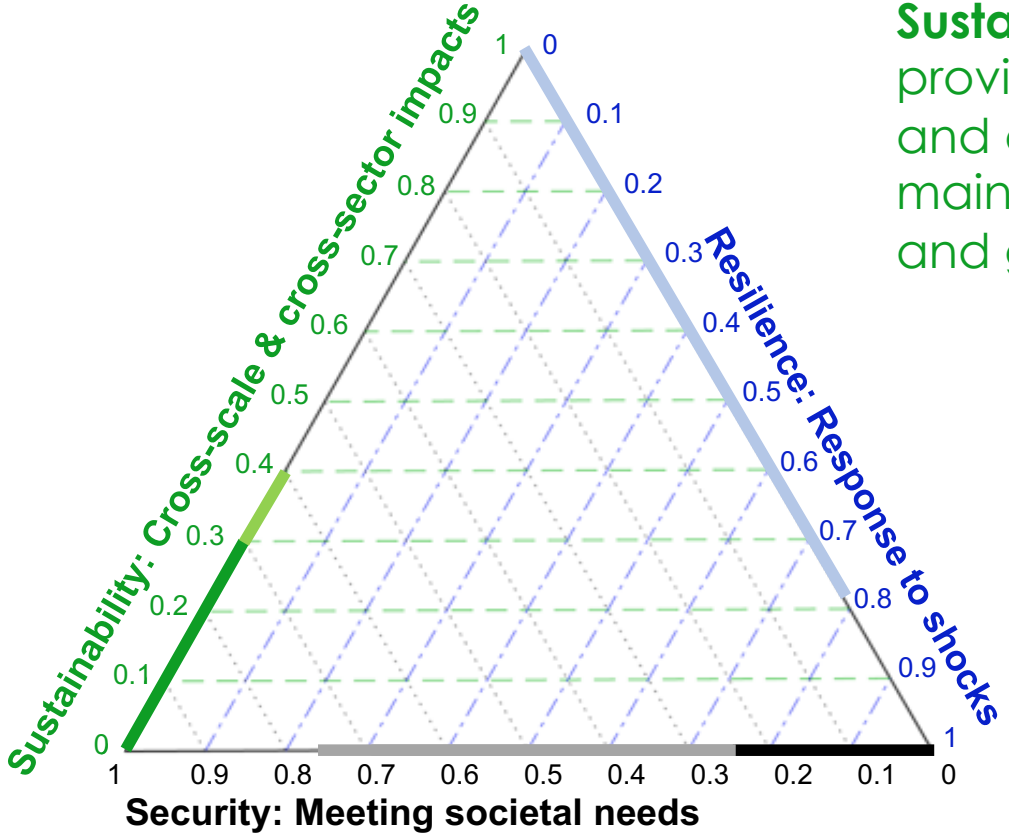
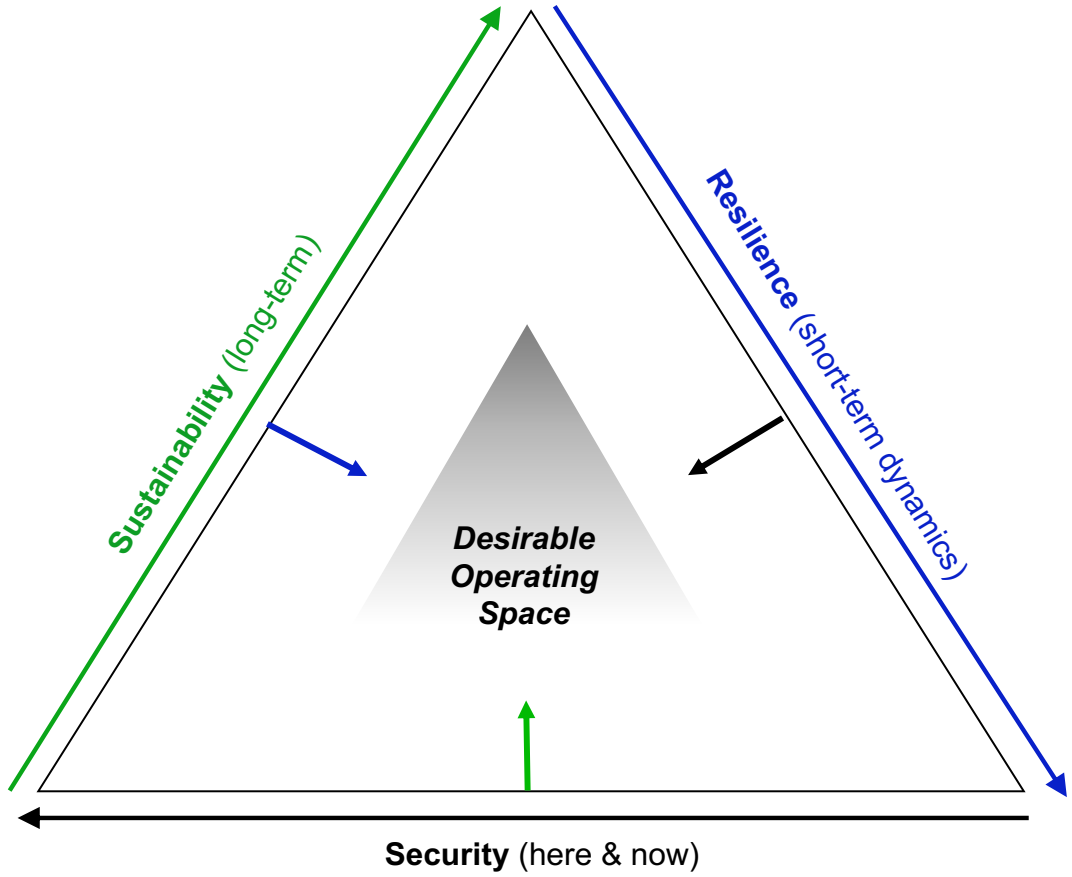


Sustainability: A system's ability to provide critical functions, equitably and over a long time horizon, while maintaining ecosystems both locally and globally

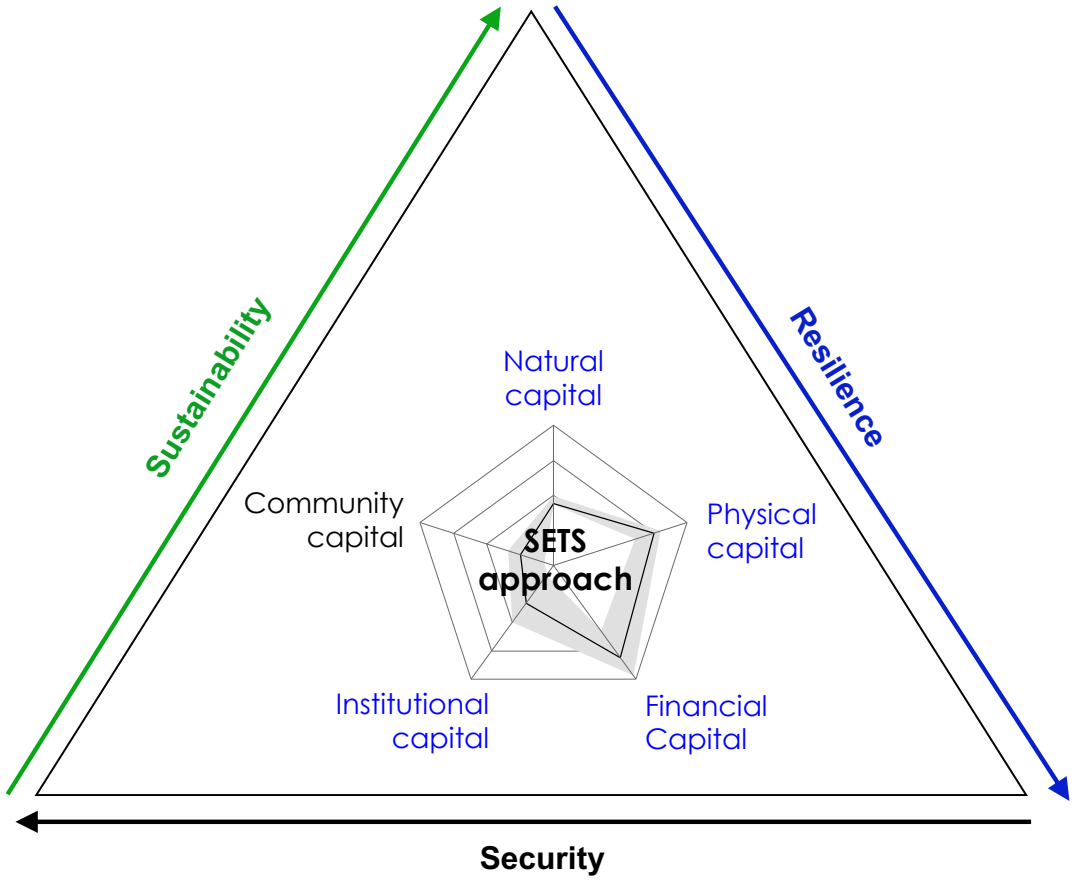
Krueger et al. (2020) ERL

Research Approach 2: Balancing Security, Resilience & Sustainability



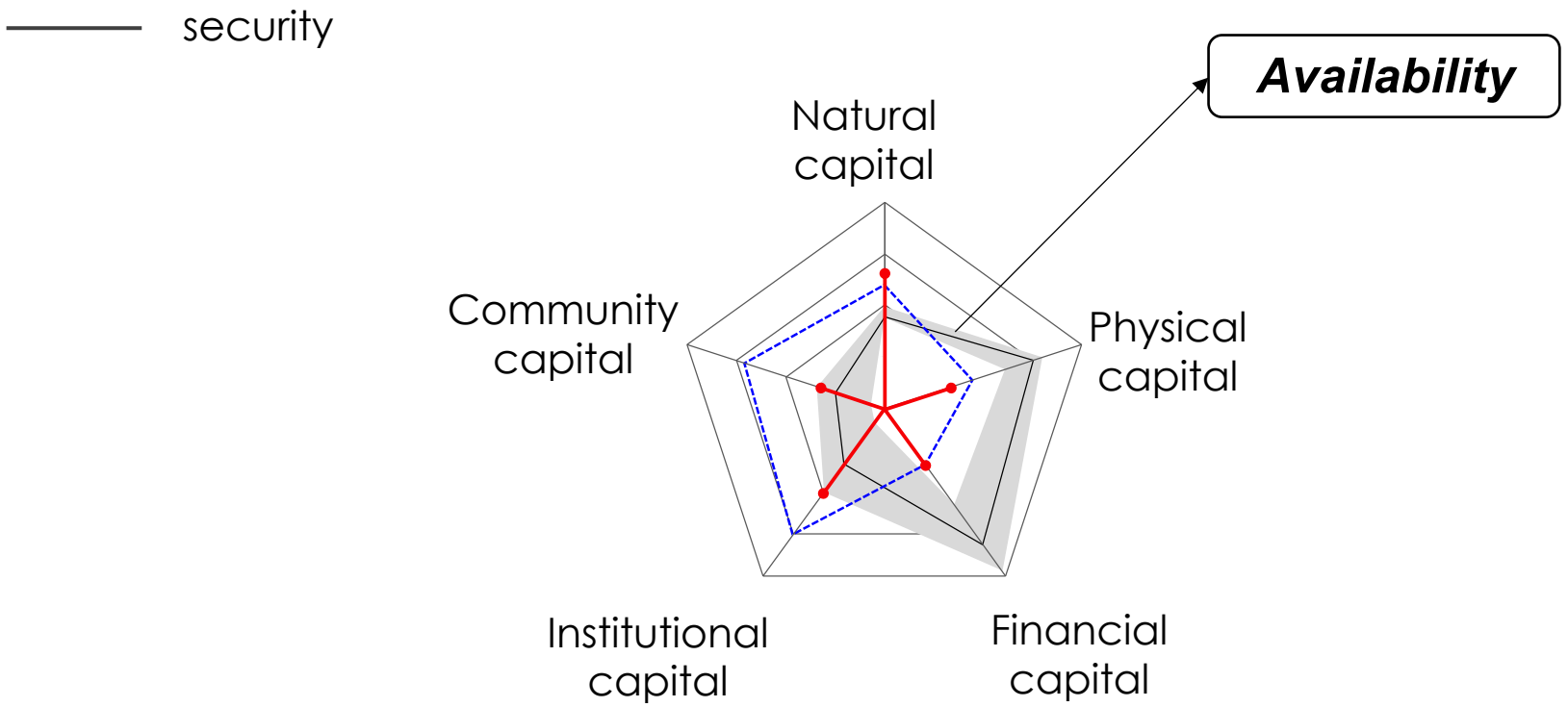
Krueger et al. (2020) ERL

Combining approaches 1 & 2



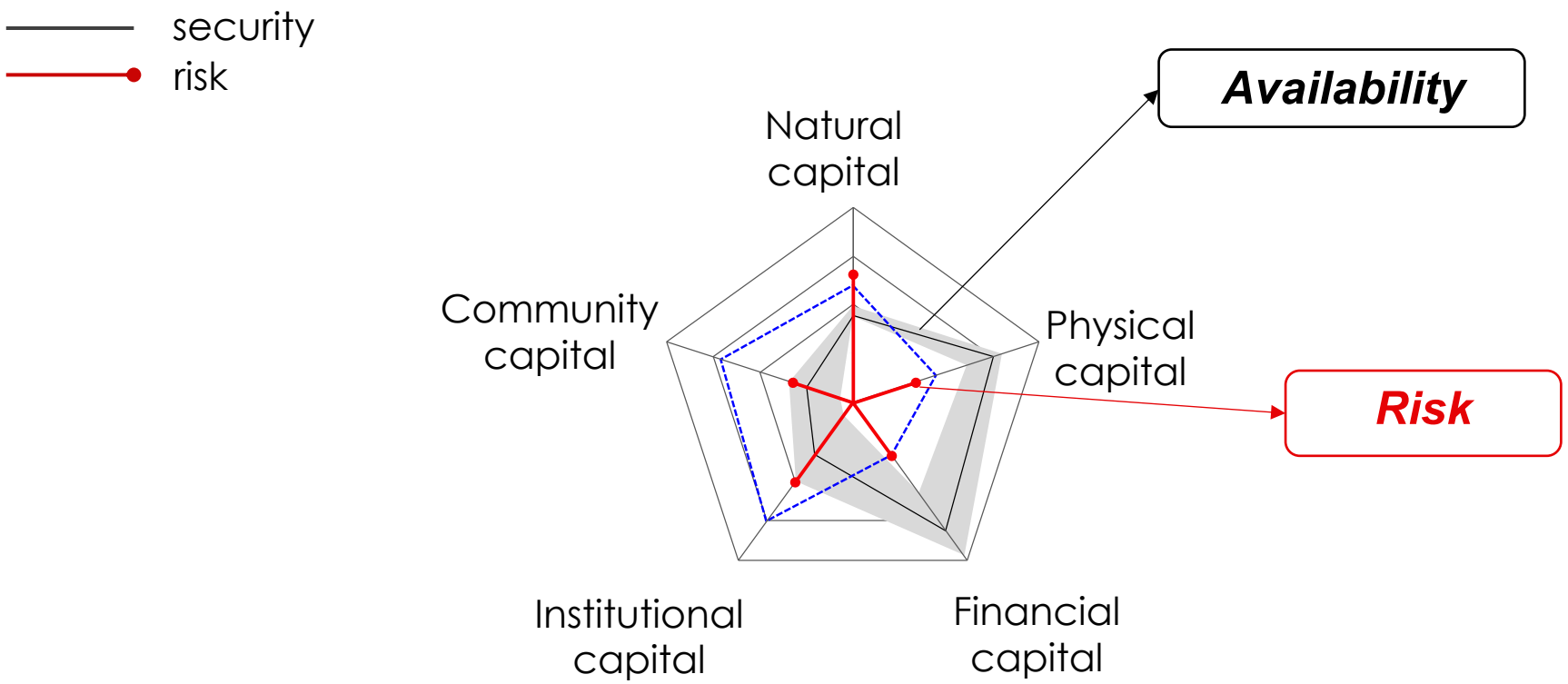
Krueger et al. (2020) ERL

Capital Portfolio Approach: Security



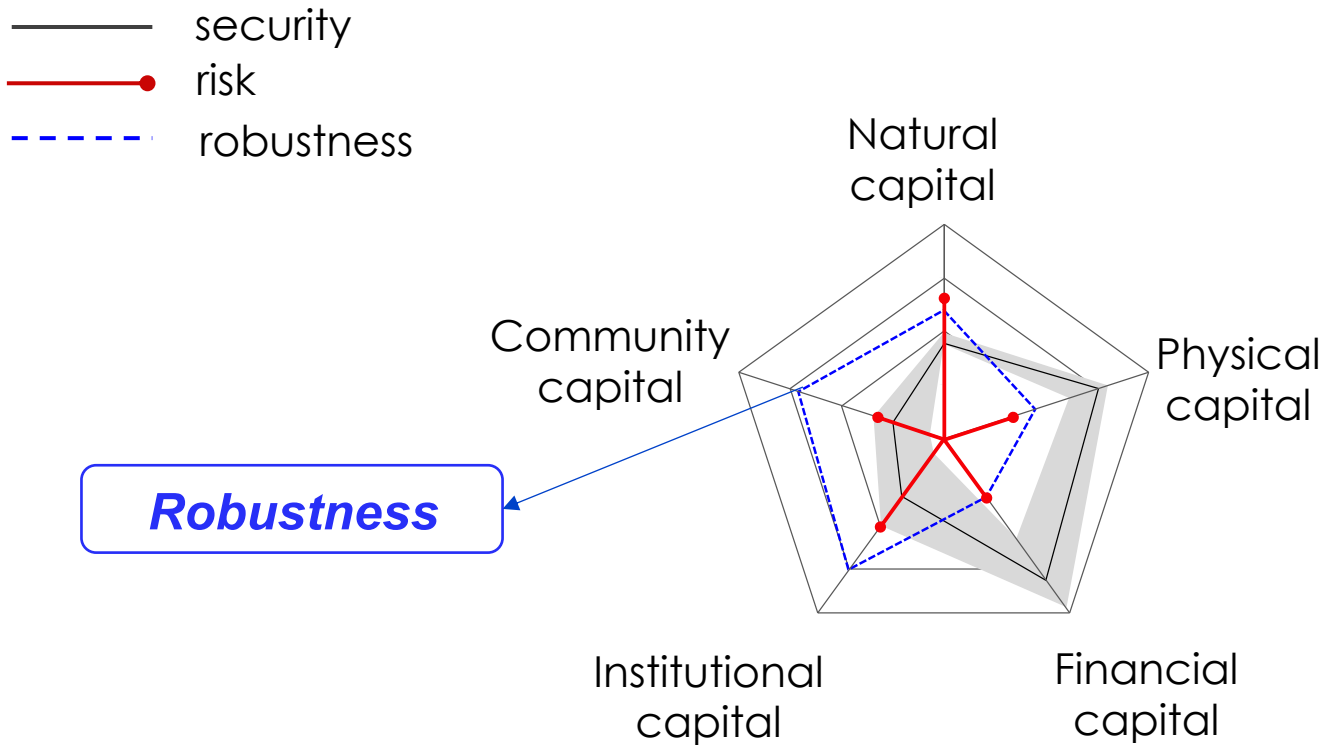
Krueger et al. (2019) GEC

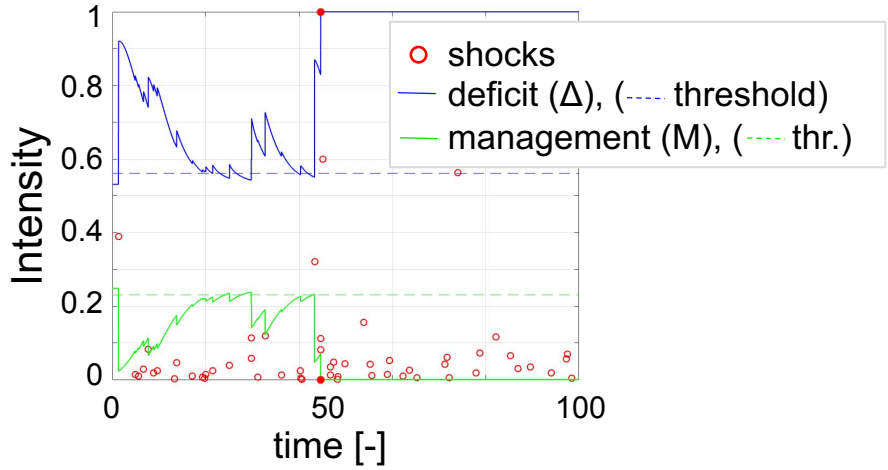
Capital Portfolio Approach: Security



Krueger et al. (2019) GEC

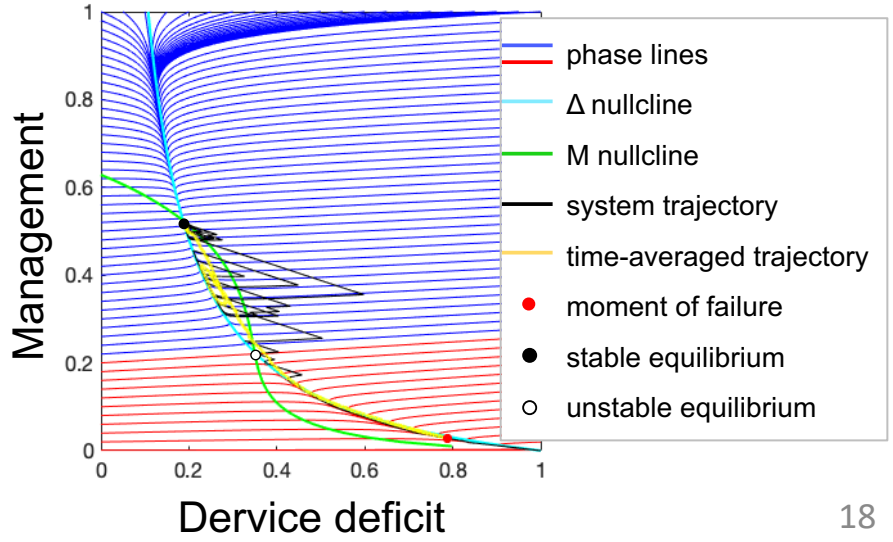
Capital Portfolio Approach: Resilience





$$\frac{d\Delta}{dt} = (1-\Delta)b - a\mathrm{M}\Delta + \xi$$

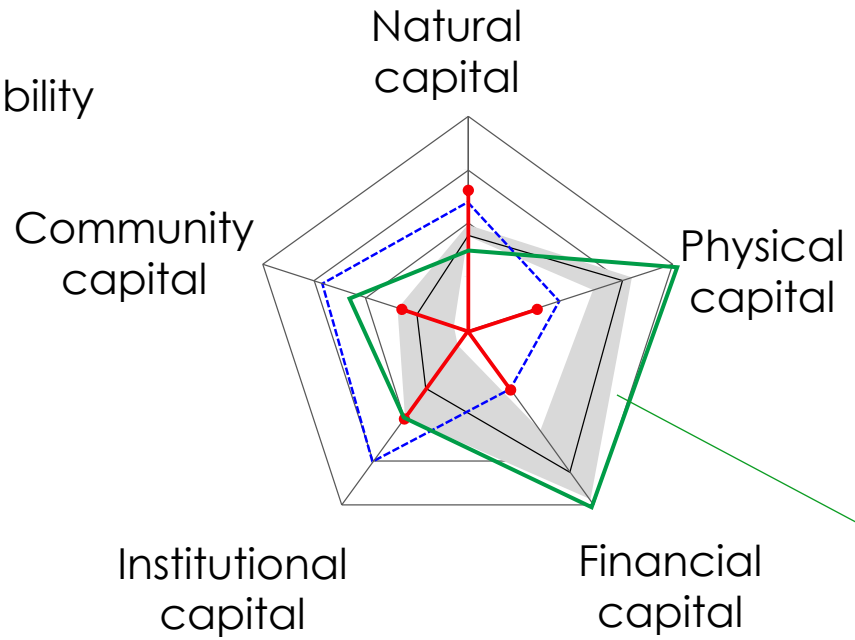
$$\frac{d\mathrm{M}}{dt} = (1-c_1\Delta)\mathrm{M}(1-\mathrm{M}) - \mathrm{r}\frac{\mathrm{M}^n}{\beta^n + \mathrm{M}^n} - c_2\xi$$

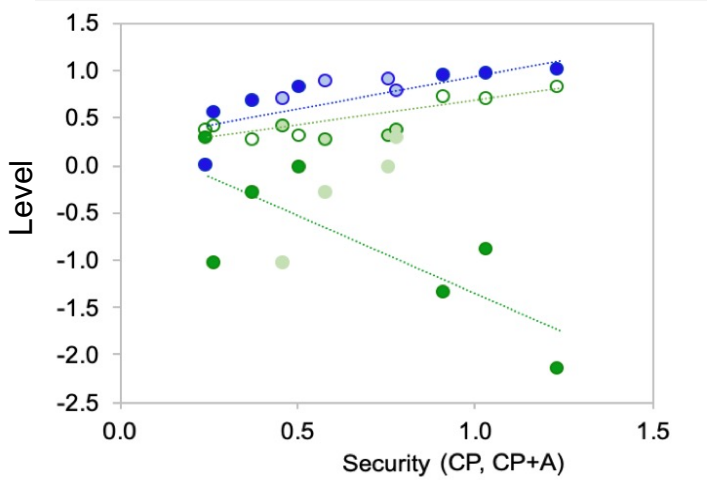


Krueger et al. (2019) GEC
Krueger et al. (2019) Earth's Future

Capital Portfolio Approach: Sustainability

security
risk
robustness
local sustainability

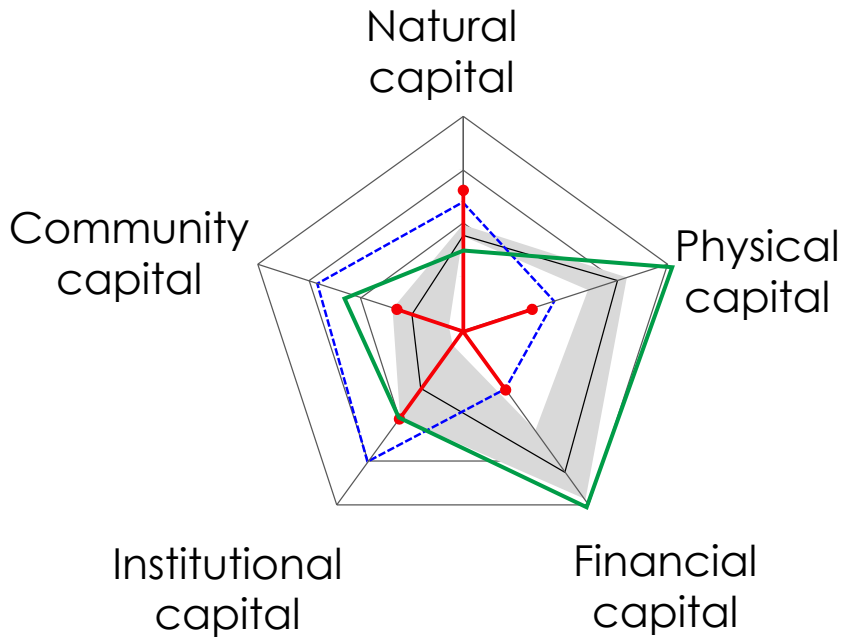




Local sustainability:
Principles of a circular economy
Global sustainability:
Global footprints of consumption

Krueger et al. (2019) GEC

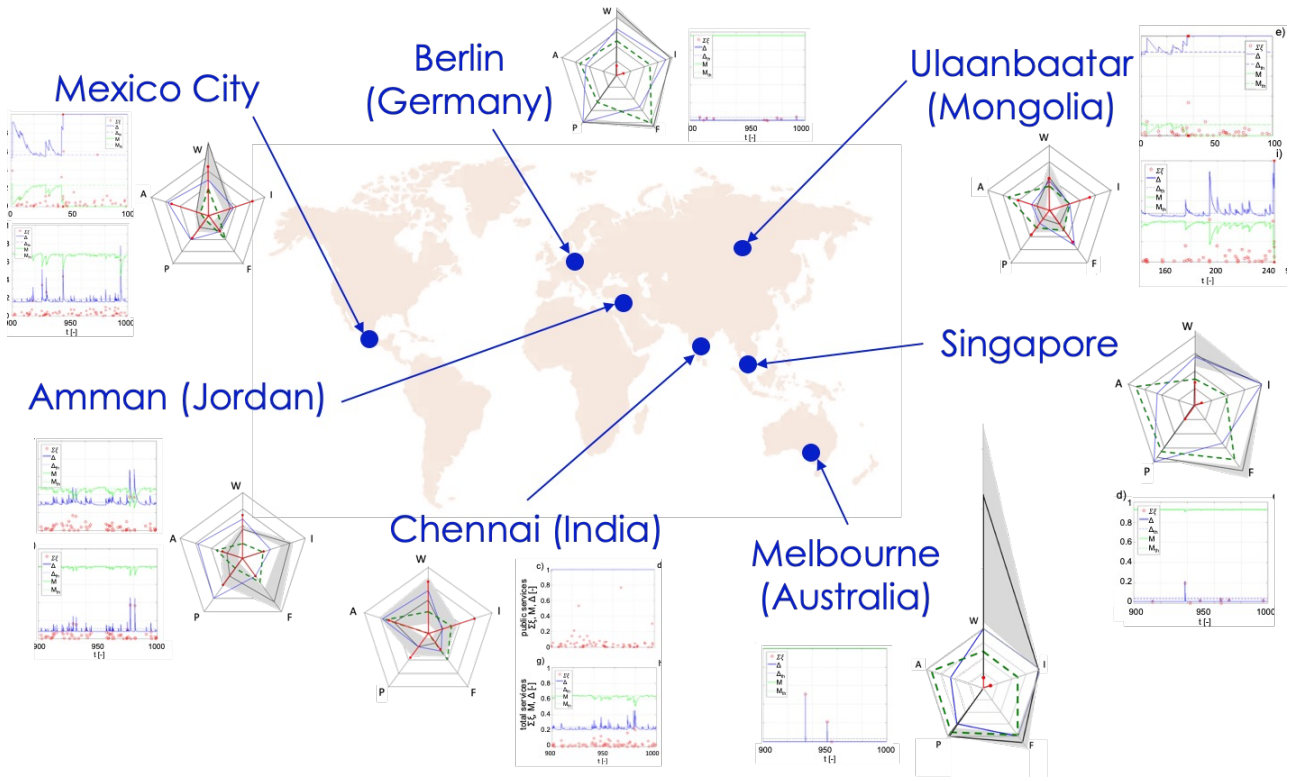
Capital Portfolio Approach

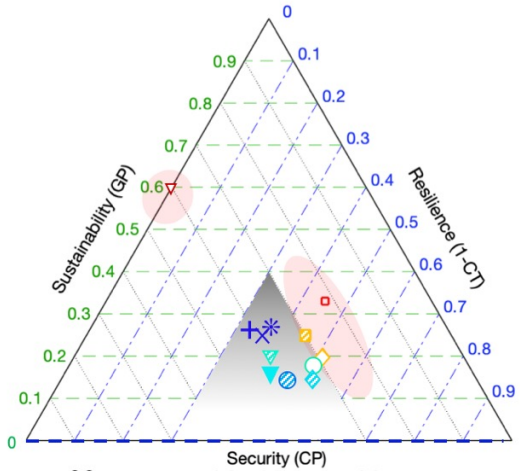


All capitals are normalized to a standard!

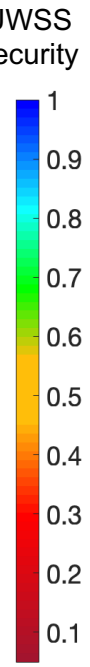
Krueger et al. (2019) GEC

Application across case studies



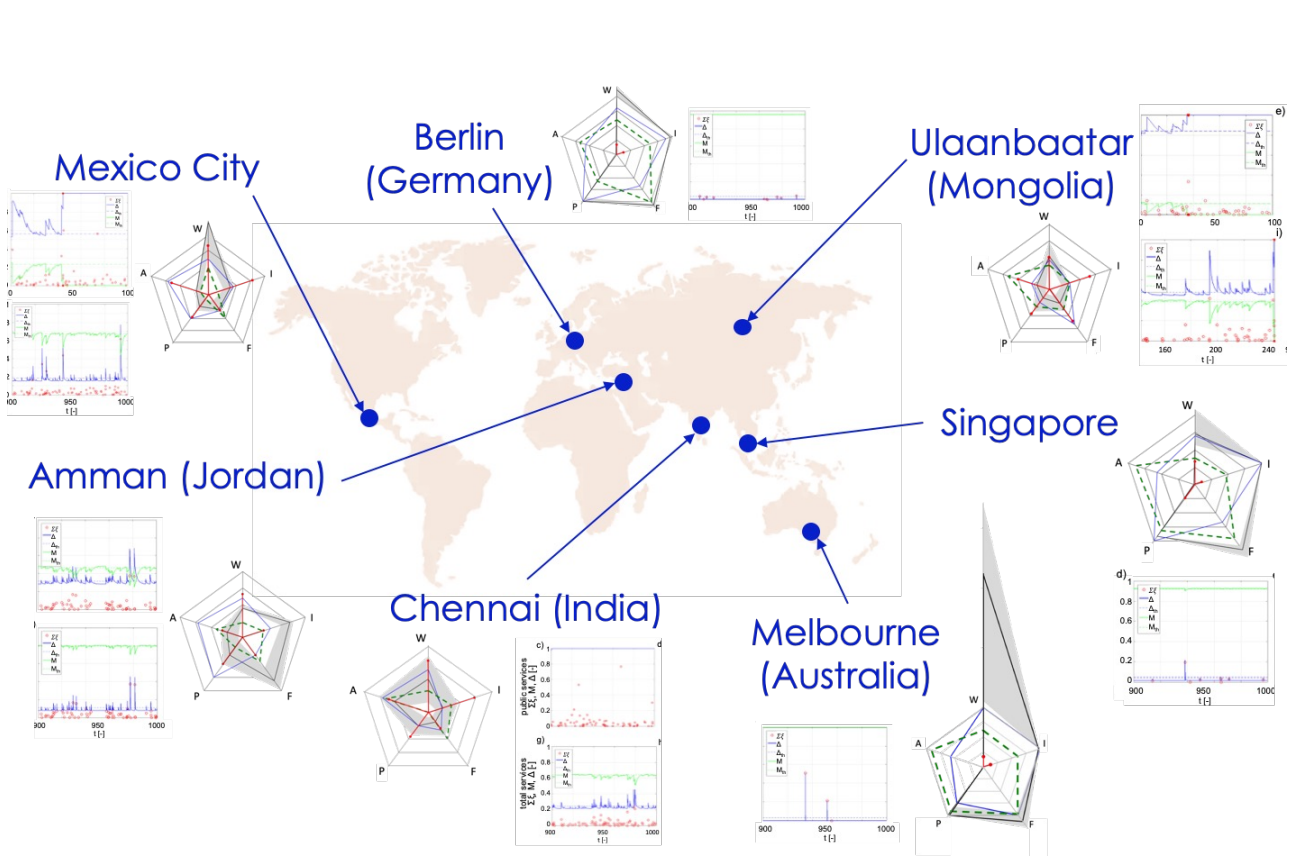


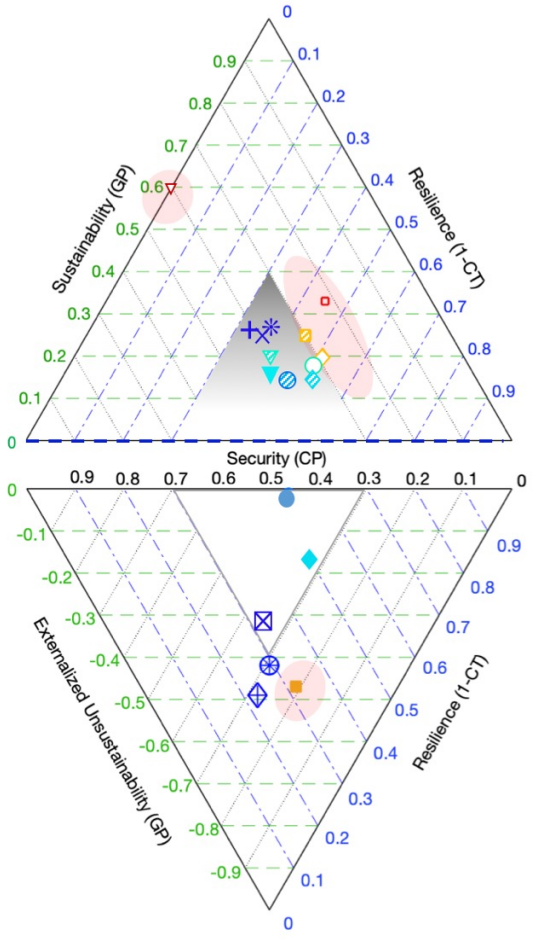
services	public	total (public+A)	
sustainability	local		global
Melbourne	+		⊕
Berlin	×		⊠
Singapore	✳		⊛
Amman	○	◍	●
Mexico City	◇	◈	◆
Chennai	▽	▼	▼
Ulaanbaatar	□	▨	■



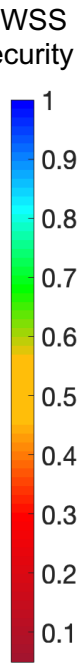
Krueger et al. (2019) GEC
Krueger et al., (2019) Earth's Future
Krueger et al., (2020) ERL

Sustainability Tradeoffs





services	public	total (public+A)
sustainability	local	global
Melbourne	+	⊕
Berlin	×	⊠
Singapore	✳	⊛
Amman	○	●
Mexico City	◇	◆
Chennai	▽	▼
Ulaanbaatar	□	■

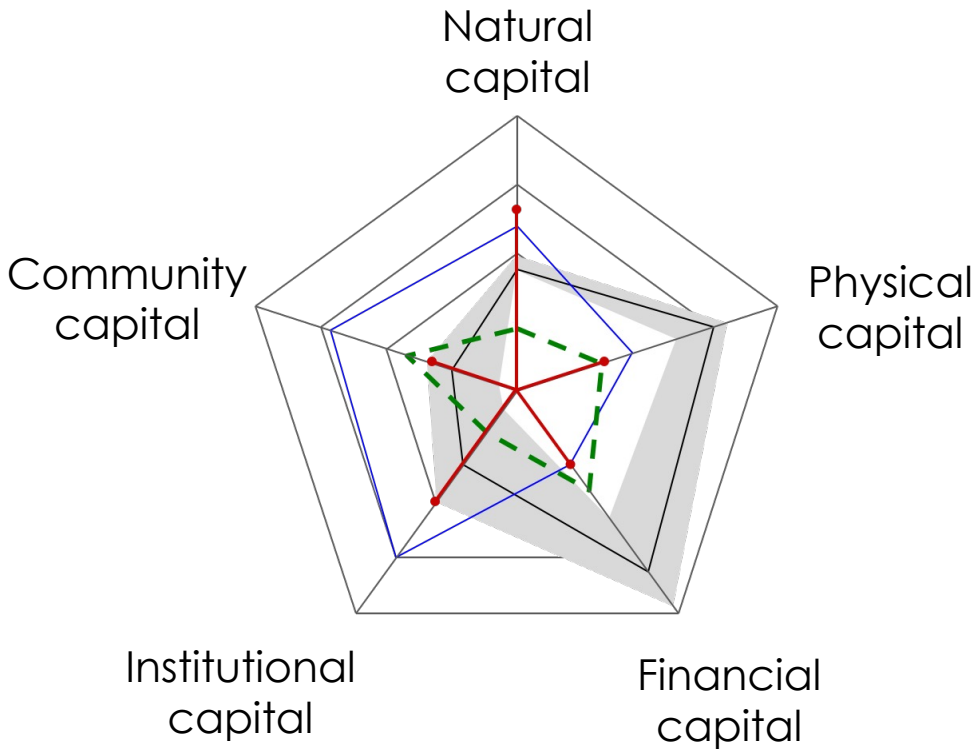


Ecosystem impacts: Footprints of consumption exceed global carrying capacity

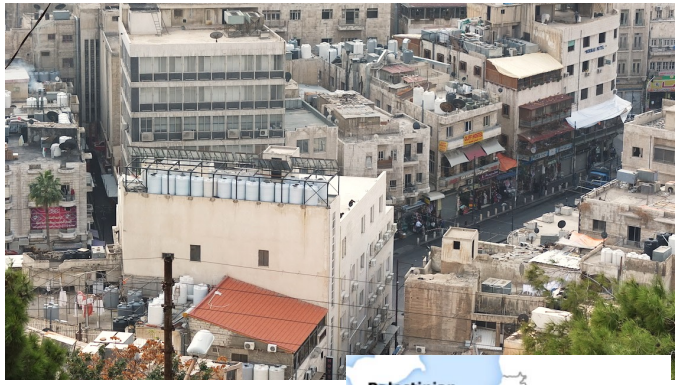
Krueger et al., (2020) ERL

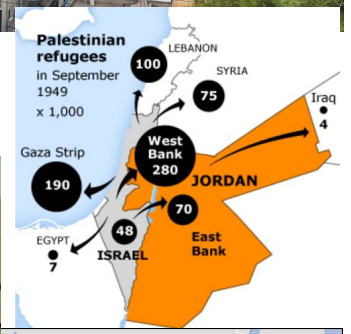
An example

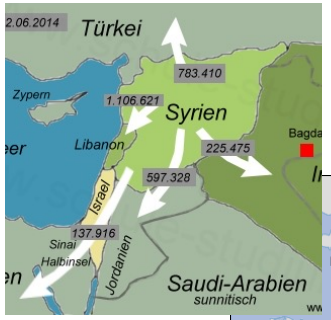
An example: Amman (Jordan)

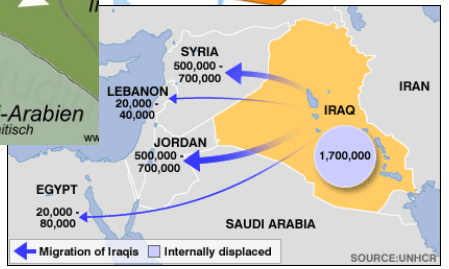


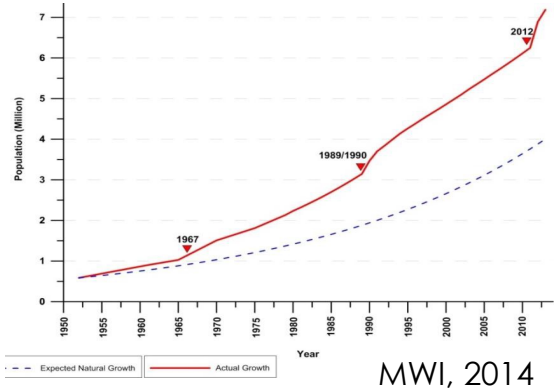
Krueger et al., (2020) ERL





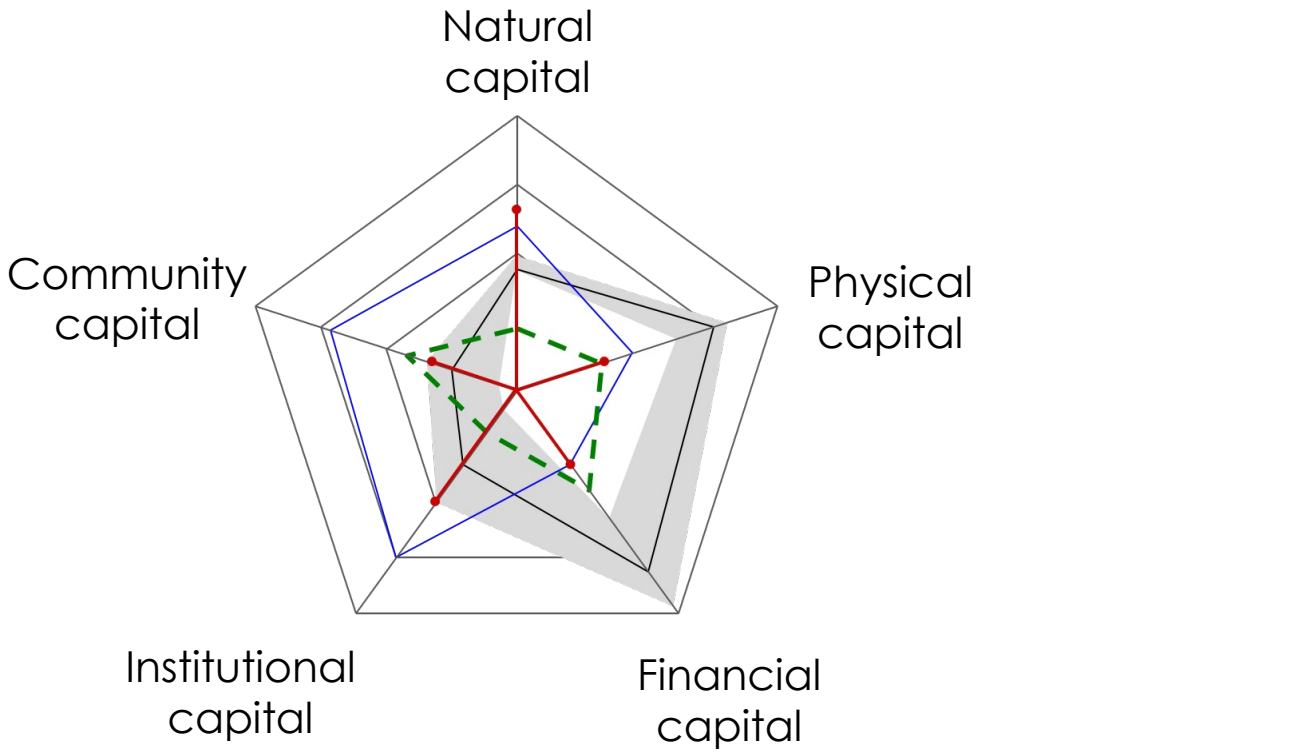


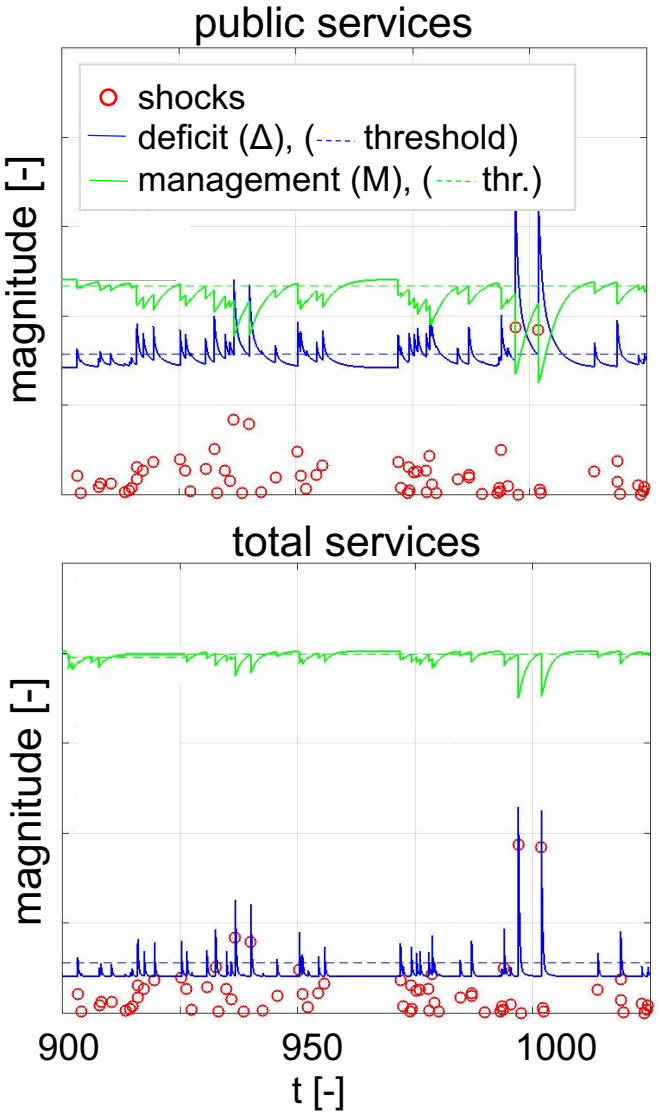




MWI, 2014

An example: Amman (Jordan)





Krueger et al., (2020) ERL
Krueger et al., (2019) Earth's Future

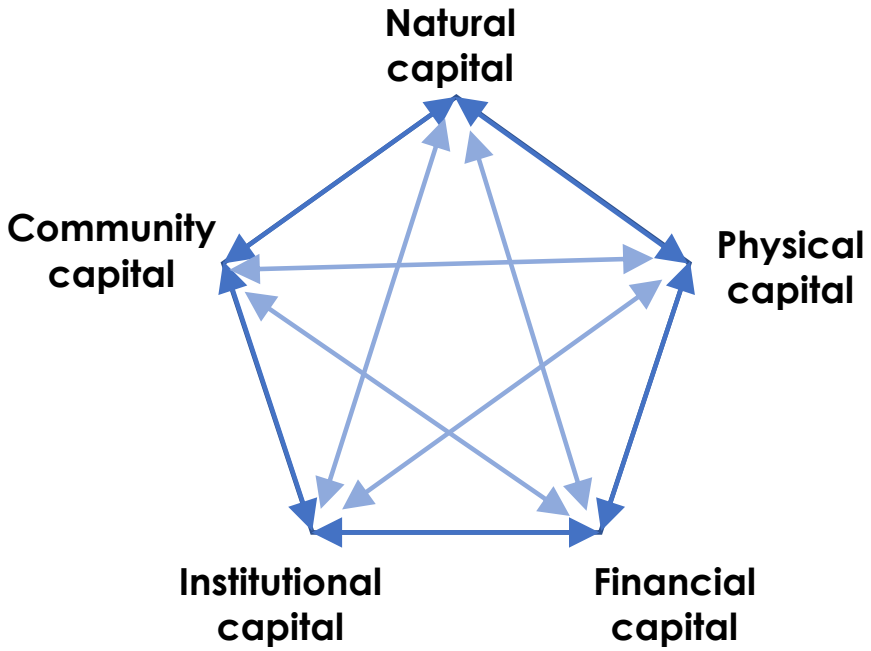
What to transition to?

How to transition towards greater sustainability?

Transformative capacity:
The capacity for change when the current system becomes untenable.

But:
Where/When/How to intervene?

System Transformations



We need to understand interaction processes between system elements, moving away from a technocratic view of the system, to including human perceptions and (irrational) behaviour.

Krueger et al. (in prep)

Data collection & analysis

1. Individual responses

- Household survey (N=300)
- Expert interviews (N=30)

- Perceived challenges to urban water supply and response to deficits

- Social actor feedbacks

2. Group perspectives

→ *Households*

→ *Local water managers*

→ *International experts*

3. System-level feedbacks

→ *Basis for improved model conceptualization*

Responses

Group perspectives

Solutions

Local Water Managers

"Deficits"
(water, finances, infrastructure) → access additional resources

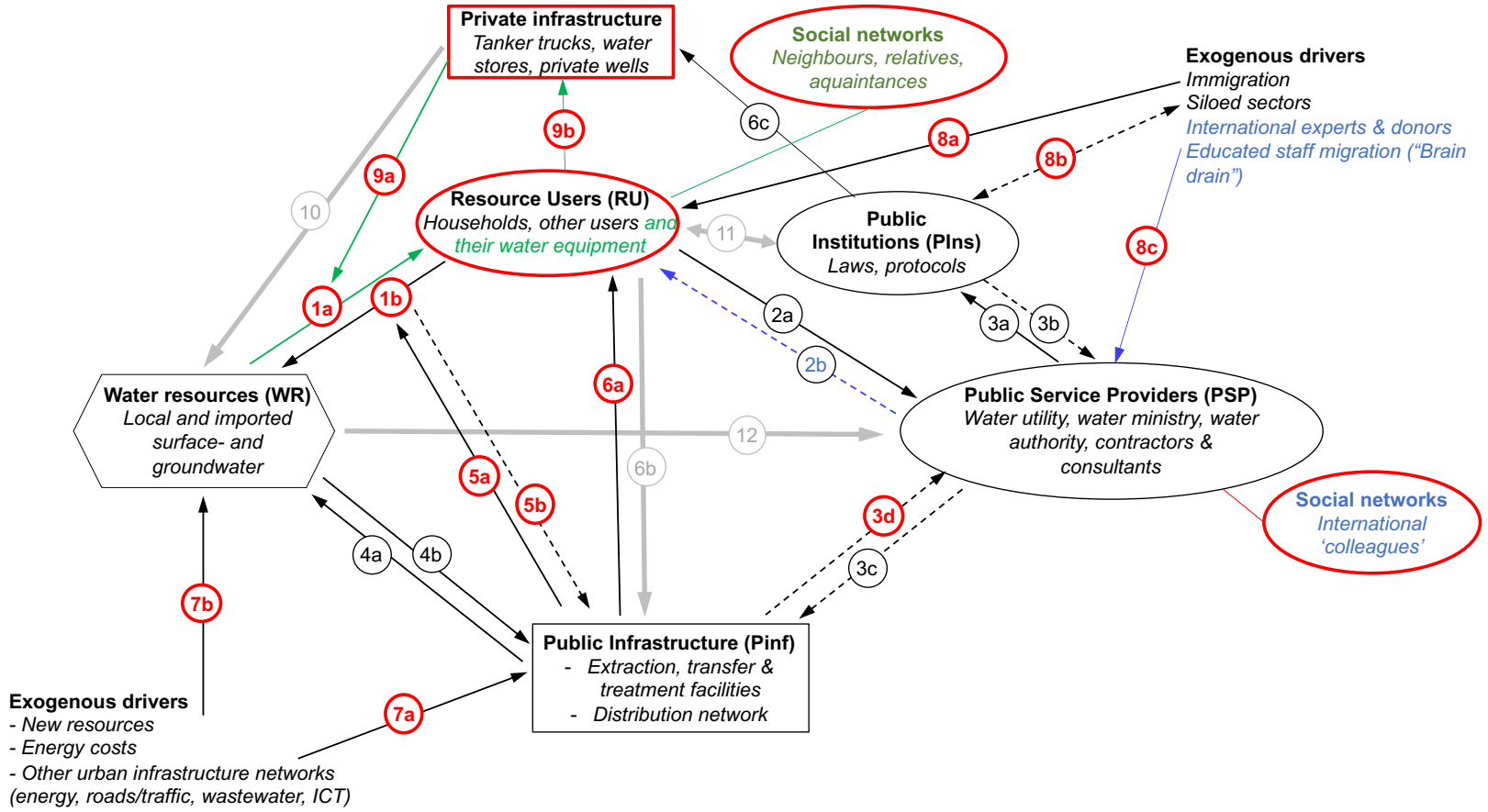
International experts

"Inefficiency"
(water, information flows, decision-making, etc.) → improve efficiency

Households

Continuity/reliability
Water quality → local adaptation

System level feedbacks & uncertainties

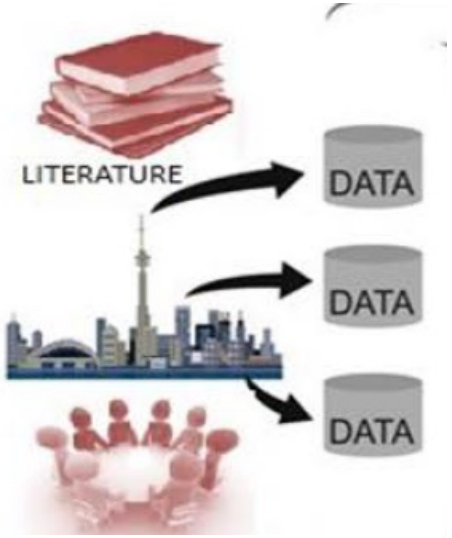


Krueger et al., (in review)

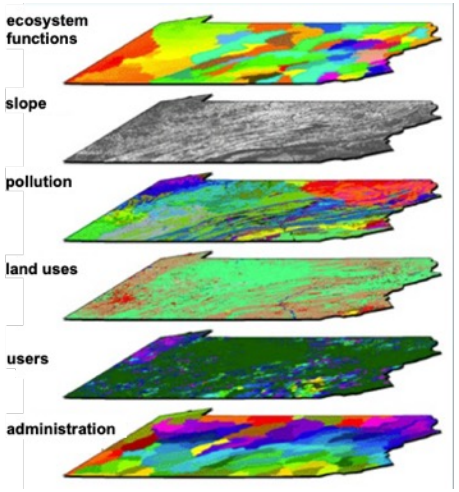
Knowledge production chain

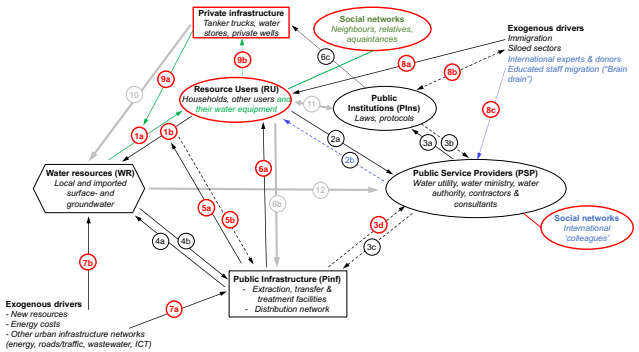
(POLDER approach)

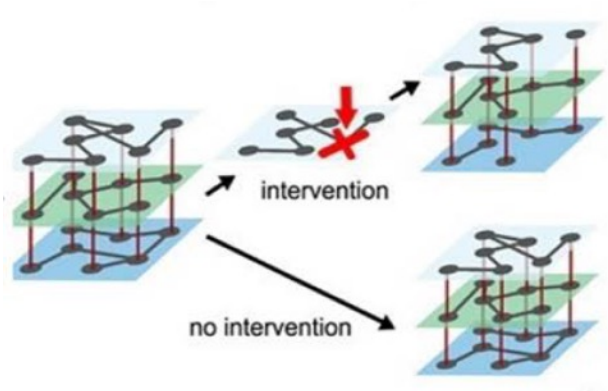
Data & information → **Spatial & functional mapping** → **Network & system dynamics models** → **Scenario pathways towards desirable future**

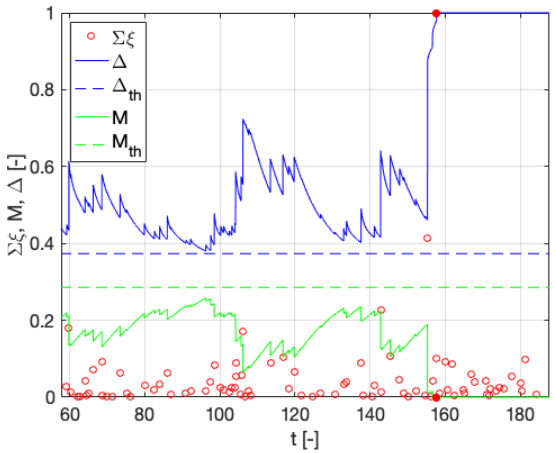


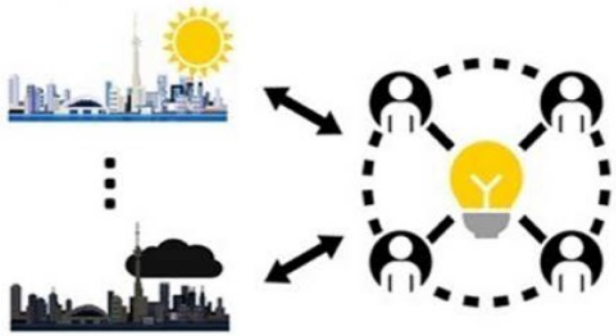
STAKEHOLDER KNOWLEDGE











Mutual learning, model development & 'what-if?' scenarios

The Polder Approach

Co-Creation
Group model building with Policymakers

Computational Modeling

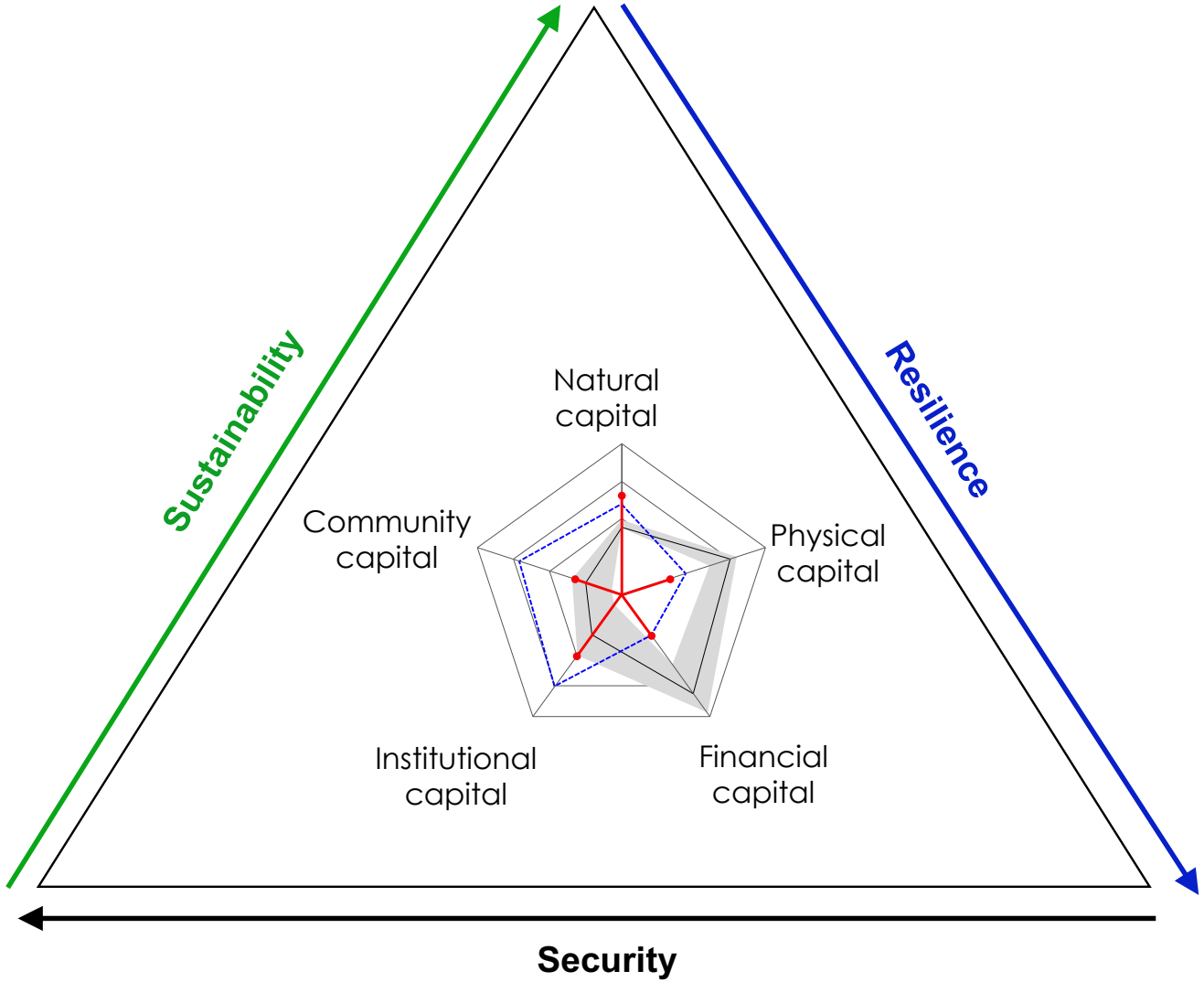
What-if scenarios
A "virtual playground" for policymakers

So:
What about energy systems?

Energy Systems

Ex: Energy security in NH

Energy Systems



Define capitals, e.g.,

- water
- land
- natural resources
- ecosystem services

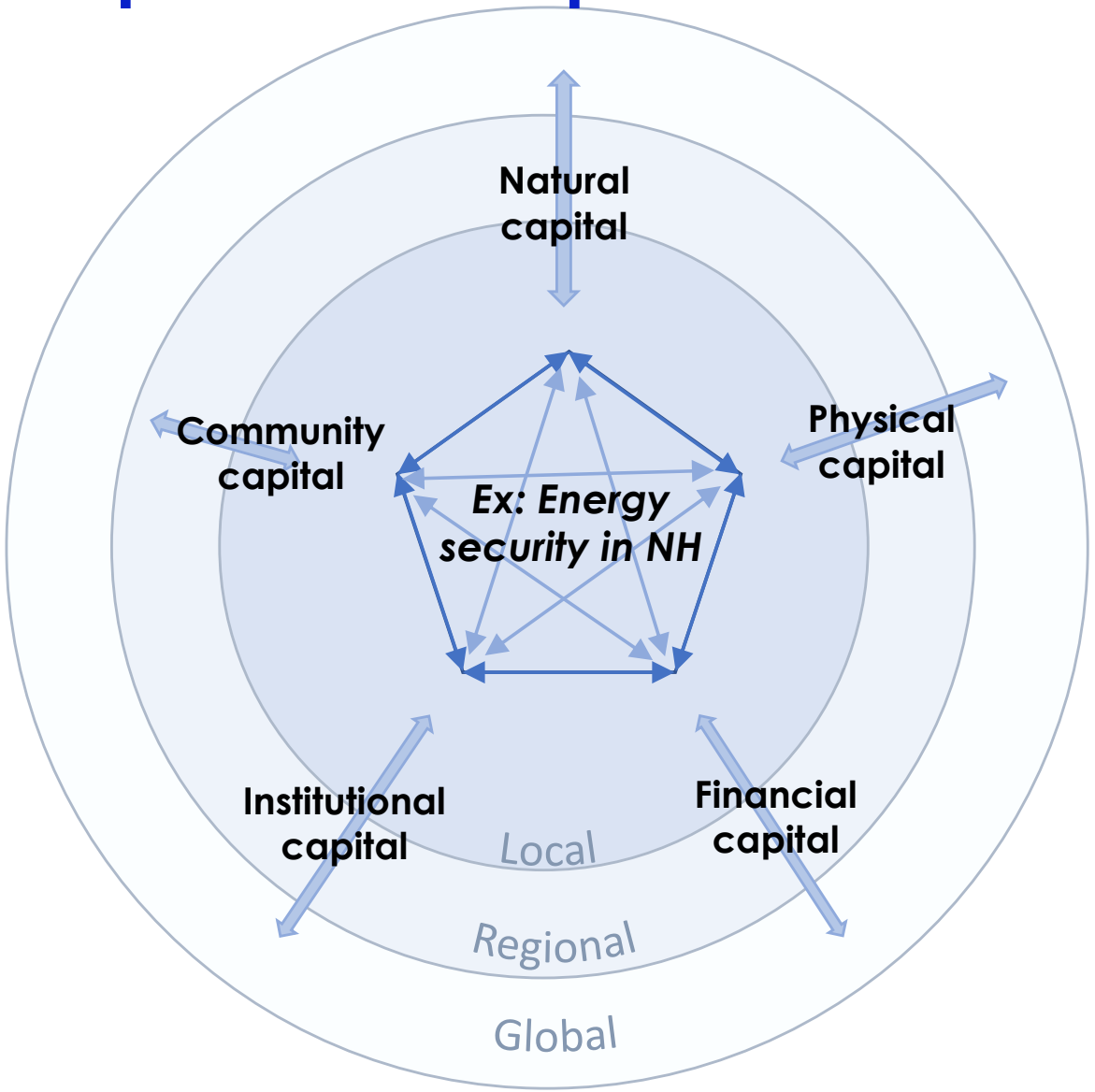
- built infrastructure
- technologies

- investments
- salaries/wages
- subsidies

- rules, regulations, policies
- effective management

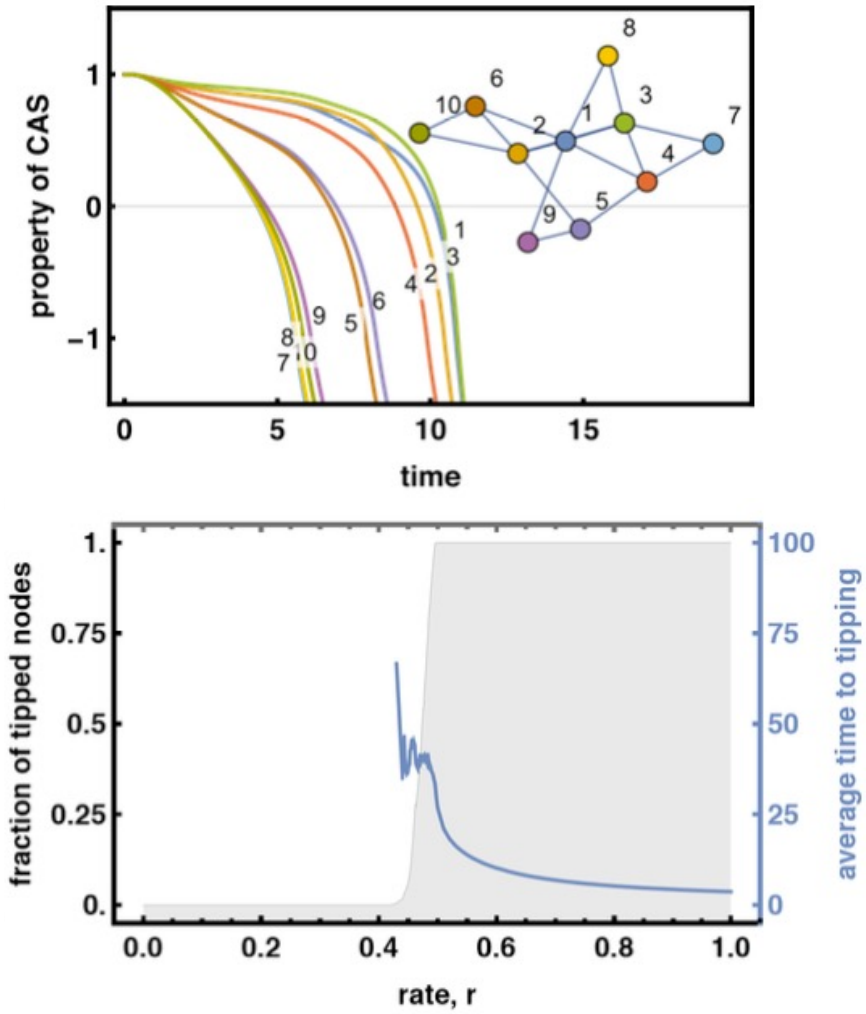
- adaptive capacity
- community support/ opposition
- individual & group behaviour

Energy Systems: Spatial & Temporal scales



Krueger et al. (in prep)

Temporal mismatches in SETS transitions?

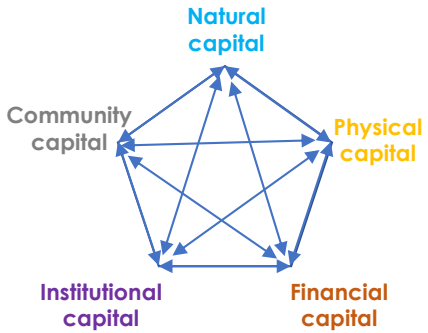


(2023) preprint arXiv:2309.07449

Rate-Induced Transitions in Networked Complex Adaptive Systems:

Exploring Dynamics and Management Implications Across Ecological, Social, and Socioecological Systems

Vítor V. Vasconcelos[+1,2,3], Flávia M.D. Marquitti[+4,5], Theresa Ong[+6], Lisa C. McManus[+7], Marcus Aguiar[4], Amanda B. Campos[8], Partha S. Dutta[9], Kristen Jovanelly[6], Victoria Junquera[10], Jude Kong[11], Elisabeth H. Krueger[12], Simon A. Levin[10,13], Wenying Liao[14], Mingzhen Lu[15], Dhruv Mittal[1], Mercedes Pascual[16], Flávio L. Pinheiro[17], Juan Rocha[18], Fernando P. Santos[1], Peter Sloot[1,2], Chenyang (Crispy) Su[6], Benton Taylor[14], Eden Tekwa[22], Sjoerd Terpstra[19,20], Andrew R. Tilman[21], James R. Watson[24], Luojun Yang[13], Senay Yitbarek[23], Qi Zhan[16]



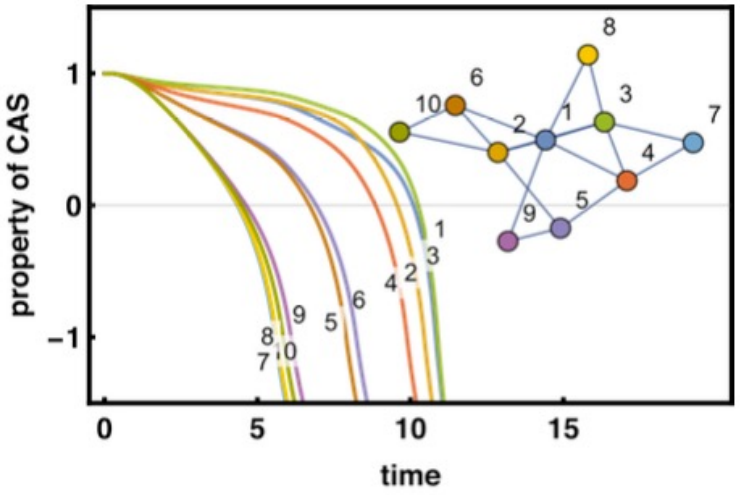
Take home message:

Interventions for sustainability must account for
- feasibility
(technological, ecological, socio-political)
- desirability (sustainability tradeoffs!)
- different scales/rates (bottlenecks/accelerators)
of each SETS element and their interactions!

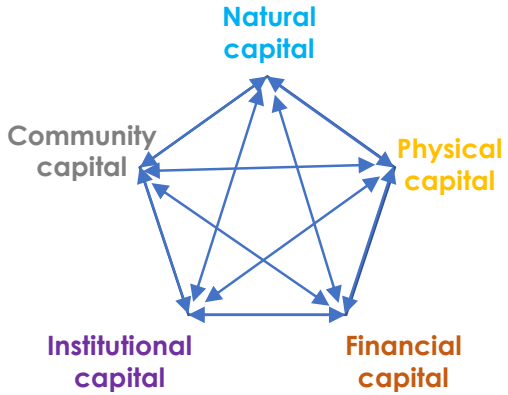
Outlook

Networked energy transition model focused on bottlenecks resulting from different rates of change in sub-systems.

ENLENS workshop on transitions in networked systems: Your ideas are welcome!



Vasconcelos et al. (2023) arXiv



Thank you!
Questions? Ideas?

References:
Krueger E, Borchardt D, Rao, PSC, 2019: Quantifying Urban Water Supply Security Under Global Change. *Global Environmental Change*, 56, 66-74.

Krueger E, Jawitz JW, Borchardt D, Klammler H, Yang S, Zischg J, Rao PSC, 2019: Resilience Dynamics of Urban Water Supply Security and Potential of Tipping Points. *Earth's Future*, 7 (10), 1167-1191.

Krueger E, Borchardt D, Jawitz JW, Rao PSC (2020): Balancing Security, Resilience, and Sustainability of Urban Water Supply Services in a Desirable Operating Space. *Environmental Research Letters*, 15 (3).

Vasconcelos VV, et al. 2023: Rate-Induced Transitions in Networked Complex Adaptive Systems: Exploring Dynamics and Management Implications Across Ecological, Social, and Socioecological Systems. (2023) preprint arXiv:2309.07449.

Master theses:

Agüero S, 2023: Just a Transition to Net Zero? Considerations of Justice within the Energy Transition in Colombia. University of Amsterdam.

Keipp M, 2023: Wind turbines: The importance of accounting for peat soil emissions to reach renewable energy targets. University of Amsterdam.

La Bruna G, 2022: Improving existing carbon accounting method for an international wood pellet supply chain. University of Amsterdam.